



Precision airdrop

A Screamer 10K hybrid decelerator is borne beneath recovery parachutes. U.S. Army photo by Joe McGrath.

Military resupply and humanitarian relief in regions with ongoing hazards can be provided quickly by an airdrop of necessary material. However, airdropping these resources safely to the intended parties requires precision. In the past, precision airdrop was accomplished only from low altitude. But recent advances sponsored jointly by the Army Natick Soldier Research, Development and Engineering Center (NSRDEC), Air Force Air Mobility Command, and others have enabled precision airdrop from high altitude, taking the carrier aircraft out of reach of ground threats.

These advances include provision of all available atmospheric data to aircraft carrying supplies to the drop location. This in turn enables ballistic parachute airdrops from locations that ensure accurate payload arrival, and it allows in-transit updates to mission plans for GPS-guided airdrop systems. Cargo airdrop systems of this nature have already been demonstrated for a variety of weight classes up to 30,000 lb.

These very significant improvements in airdrop capability justified the rapid fielding of some of these systems into current combat the-

aters during the summer of 2006. Their initial use was successful.

The Joint Precision Airdrop System (JPADS) program is the overarching effort to develop these capabilities. Government agencies set the program direction and goals, and a team of contractors is developing the needed software, avionics, airdrop technologies, and other systems.

A new planning tool

A key enabler for JPADS is the new Mission Planning (MP) tool, which is standardized for broad DOD use. Draper Laboratory, under NSRDEC management, is leading development of the MP software and user interface. Planning Systems provides the MP hardware and atmospheric data assimilation software, supported by the National Oceanographic and Atmospheric Administration's Earth Systems Research Laboratory. The MP already supports a variety of GPS-guided cargo and personnel airdrop systems, plus a range of ballistic parachutes. Support for new systems is being added regularly.

The JPADS MP consists of a laptop computer used onboard airdrop system carrier aircraft en

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In hazardous environments from battle zones to natural disaster areas, the importance of airdropping vital supplies and material is paramount. In the past, only low-altitude airdrops could ensure precise delivery of needed resources. New technologies are now making it possible to achieve the necessary precision from high altitudes—far above threats posed from the ground—and to do so with greatly improved accuracy.

from high altitude

route to drop zones (DZs). Before flight, the MP is loaded with data concerning the payloads to be released and the weather forecasts near the expected DZs. In flight, the MP is supported by a number of other systems, including a GPS retransmission kit used inside the aircraft, drop sondes that can be released to measure in-situ weather information just prior to an airdrop, aircraft communications subsystems that directly acquire drop sonde data and convey pilot wind reports, and other weather and mission data updates conveyed via a satellite link.

The MP software assimilates its various weather data into best estimates near the DZs, plans the airdrops, provides computed air release point (CARP) data to the air crew, and wirelessly transmits mission plans to guided decelerator systems. The MP can receive and accommodate updated DZ coordinates any time until moments before airdrop payload deployment from the aircraft.

The JPADS MP enables precision airdrop performance by accounting for the details. The derived atmospheric model near the DZs accounts for the full 3D wind field, the current density profile as a function of altitude, and their projected change with time. For ballistic airdrop systems, the station in the aircraft cargo bay is considered in addition to the rollout time, canopy deployment/deceleration dynamics after release, and expected descent drag characteristics. The expected glide ratio is also factored in for guided airdrop systems.

To derive the desired mission plans, the MP uses a high-fidelity simulation of all these airdrop mission characteristics. This includes required CARPs for ballistic airdrop systems

and acceptable release envelopes for guided airdrop systems, with preferred guided system CARPs determined based on specific mission objectives. The MP can also account for multiple-payload releases on a single pass over a DZ, a maneuver known as a stick. This includes the opportunity to designate different landing targets for guided payloads in a single stick, with an acceptable CARP identified that supports the scattered targets.

The simulation can also account for modeling uncertainties and possible system failures. This enables generation of expected landing footprints for ballistic airdrop systems, potential impact locations when decelerator canopies fail, and possible touchdown location when guided airdrop system steering fails. The specific payload input information, release envelopes, and expected footprints can all be displayed in user-specified formats over maps or images of the DZ vicinity by use of the FalconView graphical map interface capability within the MP.

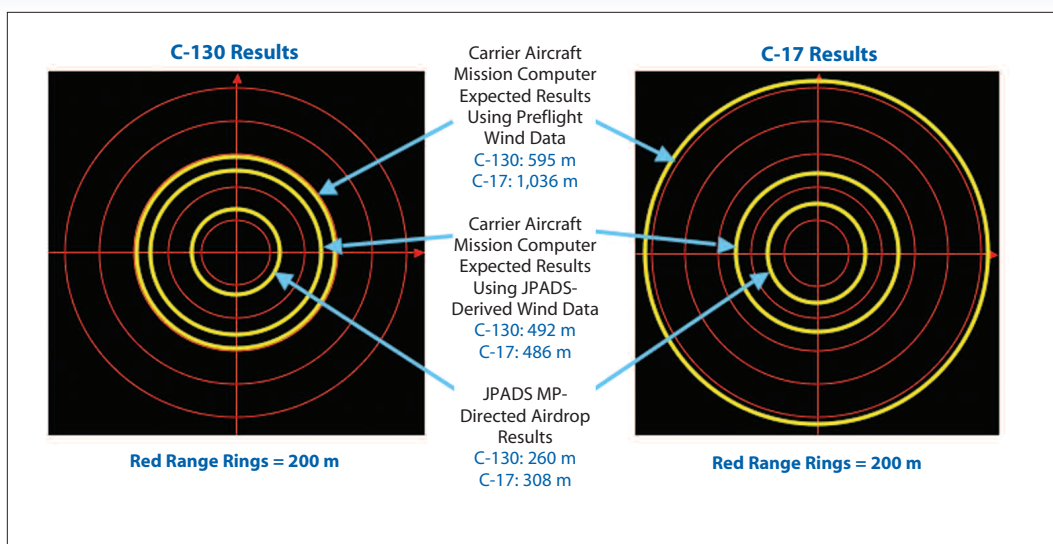
The JPADS MP has undergone substantial, realistic flight testing at



The JPADS MP user interface provides easily identifiable function selection buttons

while displaying key status and output data. The hardware comprises (clockwise from top left) a laptop, laptop-to-UHF antenna interface, UHF combiner, GPS retransmit kit, and drop sonde.

Military operational utility evaluations demonstrated that JPADS-derived wind data and the MP account for detailed airdrop system dynamics. Each contribute to significant improvement in high altitude airdrop accuracy.



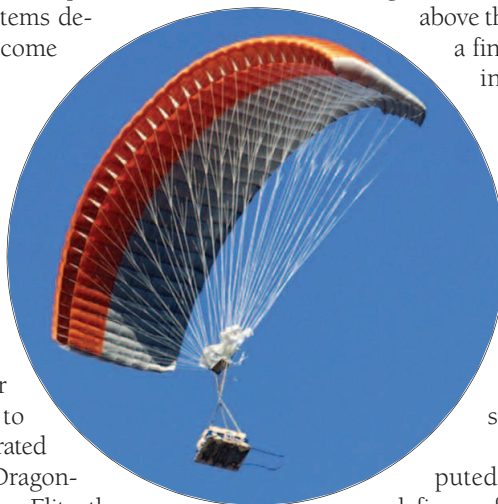
major government airdrop ranges. The USAF Test and Evaluation Squadron performed a large number of ballistic airdrops using the MP under controlled operational utility evaluation (OUE) test conditions. These enabled the JPADS-derived accuracy to be compared with the expected accuracy using prior carrier aircraft airdrop techniques.

The OUE demonstrated very substantial ballistic airdrop accuracy improvement due both to the improved wind projections from the MP and to the explicit account in the MP for the expected airdrop system release and descent dynamics. More recent tests of the MP usage in support of guided airdrop systems have also demonstrated its ability to facilitate improved delivery success with guided airdrop systems. Given these capabilities, the JPADS MP is being readied as an Air Force mission planner standard, with airdrop systems developers encouraged to become compatible with it.

Dragonfly parafoil decelerators were used to demonstrate an open-architecture, autonomous GN&C flight software package.

GN&C for parafoils

Another part of the JPADS program is development of an open-architecture, autonomous guidance, navigation, and control (GN&C) flight software package for parafoils. This is being done by Draper Laboratory under contract to Natick. Originally demonstrated on the 10,000-lb-capable Dragonfly parafoil developed by Para-Flite, the GN&C software was subsequently extended for use on the 300-lb-class Microfly and the 30,000-lb Megaflly, both also developed by ParaFlite.



Navigation provides estimates of target relative position, heading, heading rate, heading acceleration, and wind. Obtaining the needed data requires an airborne guidance unit (AGU) with applicable avionics sensors. A Kalman filter in navigation then processes the unit's sensor data into the desired state estimates. Guidance accepts the processed navigation data and derives heading rate commands for control.

The guidance flight strategy is organized into modes that correspond to the different flight phases. Far from the target, guidance generates *homing* commands—turning to and then flying toward the target. When nearing the target, guidance generates *energy management* commands to lose altitude while not straying too far. The latter is achieved by flying a figure-eight pattern oriented transverse to the desired landing direction. At a designated altitude

above the ground, guidance directs a final approach maneuver using a precomputed lookup table in which turning commands are indexed by altitude, along-track, and cross-track position (with respect to the desired landing direction), heading, and heading rate. The landing direction will normally be into the wind to reduce speed during touchdown.

The lookup table is computed before the mission and defines a family of trajectories, with the one applicable for a given flight determined based on the airdrop system state when the lookup mode is entered during flight. These

trajectories hit the target if physically possible, or minimize the error at touchdown if the target cannot be reached. Control is proportional, integral, and derivative (PID) based to make the navigated heading rate match the commanded heading rate from guidance. The control design is augmented with low-pass filtering of the heading-rate error. The estimated heading acceleration is used for the PID heading-rate derivative. The controller output is clipped so as not to exceed the actuator position limits and applies a dead band with hysteresis in order to reduce actuator duty cycles.

Recent flight tests of the GN&C software on the Dragonfly 10,000-lb-class parafoil used an AGU developed by Wamore. The tests demonstrated an expected landing accuracy capability of about 150 m. There are also other decelerator types with their own airborne guidance units and autonomous flight approaches.

Airdrop system types

Many different aerodynamic decelerators (air-drop system canopies) are used with the MP. These include ballistic round parachutes and three distinct types of guided decelerators in the JPADS family of systems: parafoils, guided rounds, and hybrids. A parafoil deploys to a canopy geometry that generates lift in its forward motion, generally with an elliptical planform. Steering left and right is provided by control lines that pull down either side of the trailing edge using actuators suspended well below the canopy (at or near the payload).

Parafoils are more expensive than round parachutes but enable releasing the loads with a large horizontal offset from the target. They also allow precision landing, since they can be controlled from deployment through landing and have high glide ratios. These systems must flare near the ground to reduce payload forward (and vertical) velocity.

Hybrid systems employ a parafoil for most of their flight, but at a point above the ground target (biased for predicted wind drift) they release conventional round recovery parachutes that eliminate lateral motion before touchdown. The potentially smaller and simpler hybrid gliding canopies have reduced actuation requirements, since no flare is needed. This makes them less costly than pure parafoil systems. But because final descent is ballistic, their accuracy potential is degraded by uncertainties in the near-surface winds. Hybrids have a smaller glide ratio than pure parafoil systems, providing moderate horizontal offset capability for their aerial release.

Guided round parachutes are the least expensive because they are manufactured in great



The Screamer 2K had its first operational drop over Afghanistan in August 2006.

quantities. They accomplish directional control via riser line slips that distort the round canopy shape and surrounding air flow. This gives them a limited glide ratio, and therefore the least release point horizontal offset capability of the three guided decelerator types.

Both hybrid and parafoil systems will soon accommodate interim waypoints in their trajectory between high-altitude deployment and their individual recovery phases.

Strong Screammers

With both internal and NSRDEC funding, Strong Enterprises developed a family of 2,000-lb (2K) and 10,000-lb (10K)-class hybrid decelerators, termed Screammers. Both variants use the same

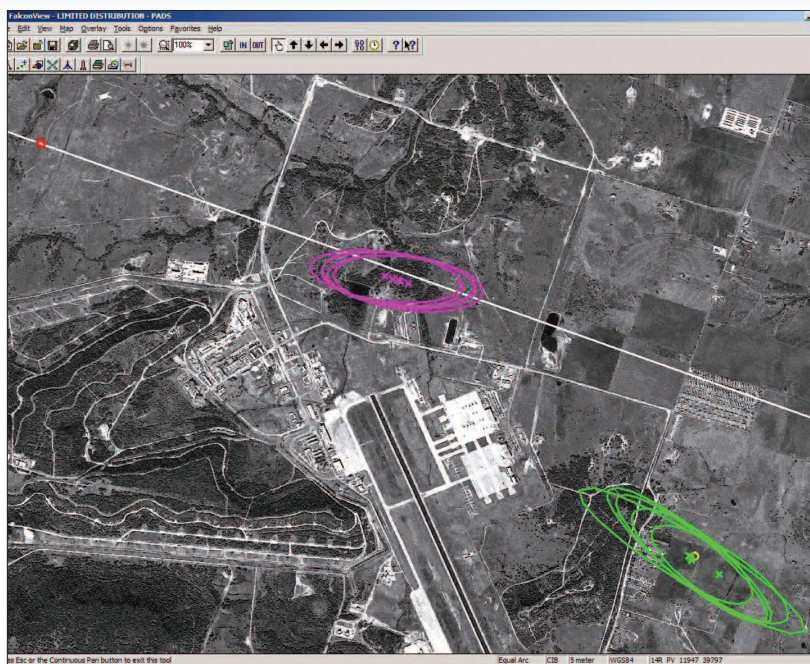
JPADS Program Participants

Government Agencies

DUSD – Advanced Systems and Concepts
NOAA Earth Resources Research Lab
Office of the Secretary of Defense
USA Natick Soldier Research, Development and Engineering Command
USA PM, Clothing and Individual Equipment
USA PM, Force Sustainment Systems
USA Research Office
USA Yuma Proving Ground
U.S. Joint Forces Command
USMC
USN Naval Sea Systems Command
U.S. Special Operations Command
U.S. Transportation Command
USAF Mobility Systems Wing
USAF Air Mobility Command
USAF Air Mobility Warfare Center
USAF Electronic Systems Center
USAF Test and Evaluation Squadron

Industry

Atair Aerospace
Boeing
Capewell Components
Creare
Draper Laboratory
Dutch Space
EADS
ECII
Fibertek
General Dynamics
Lockheed Martin Coherent Technologies
MIST Mobility Systems
Oceanit
Paraflyte
Pioneer Aerospace
Planning Systems
Robot Solutions
Robotek Engineering
Seabox
Stara Technologies
Strong Enterprises
UTRI
Vertigo
Wamore



The JPADS MP overlays color-coded data on FalconView map displays to indicate the location of airdrop release points and expected (nominal or failed) payload delivery performance data.



Two 2,000-lb systems land near the target at Yuma Proving Ground, Ariz. U.S. Army photo by Steve Tavan.

AGU and GN&C software, supplied by Robo-Tek Engineering. Screamer autonomously navigates during ram air drogue (RAD) parafoil flight to a programmed location near the target. It then descends in a circular pattern above the target to a preset mission recovery altitude where round parachutes are deployed to arrest high-speed forward glide and affect a standard ballistic descent.

JPADS MP-derived knowledge of surface winds is applied by Screamer to resolve a recovery parachute deployment location to ensure landing accuracy. Screamer integration with the MP enables it to benefit from the multiple wind sources available to the MP and en-route mission replanning acquired from the MP. The MP also determines the Screamer CARP.

During the RAD flight phase, Screamer reaches forward air speeds up to 100 mph, allowing excellent wind penetration. The RADs are loaded up to approximately 12 lb/ft² of canopy fabric area. Screamer can accept mission plans wirelessly from the JPADS MP or an alternative MP system for non-JPADS-enabled aircraft. It can also wirelessly feed its health status to the JPADS MP for display to the carrier aircraft's loadmaster.

In August 2006, 2K Screamer systems made their operational field debut under a rapid combat fielding activity. The 10K Screamer underwent an initial joint military user assessment in June 2006. A second assessment will take place early this year. Subject to a favorable evaluation after a third, residual 10K Screamer assets will be transferred to the Dept. of Defense for its use.

AGAS

The Affordable Guided Airdrop System (AGAS), a 2K-lb-class system developed by Vertigo, is manufactured and marketed by Capewell Components. AGAS uses standard military G-12 (ballistic, round) parachutes, achieving directional control via four control lines, each separated by 90°. These control lines actuate "riser slips" to deform the parachute as would a paratrooper. A modest glide ratio, around 0.4, is achieved during the slips.

AGAS is compatible with the JPADS MP, enabling the MP's wireless use for mission plan updates en route to AGAS release. An AGAS mission plan establishes a trajectory based on the glide capability, as well as expected MP-provided CARP and wind data. The AGAS guidance approach is quite simple. During flight, whenever the current position error exceeds a set amount from the planned trajectory, the control system drives AGAS back toward the plan.

Use of standard military parachutes that are produced in great quantity makes AGAS very inexpensive. Both 500-lb and 2K-lb-capable prototype systems have been demonstrated. The 2K-lb-class AGAS systems are now in an operational theater under a rapid combat fielding activity.

Use by paratroopers

In addition to cargo delivery, the JPADS MP has found utility with paratroopers. The same up-to-date wind assimilation approaches are now being used operationally to assist jumpers in planning their missions.

Starting in 2004, the MP expanded its model set to include six different personnel parachutes in use by the U.S. military. An advanced capability is now available whereby the mission plan is provided wirelessly to electronics in the jumpers' helmets. Embedded software then provides steering queues to the jumper via a goggle eyepiece or a small tablet screen, greatly improving the landing accuracy and safety of free fall missions at night and in adverse weather.



The last four years have seen revolutionary advances in precision airdrop. The industrial base is developing whole families of parachute systems that span a very wide weight range. The mechanics, mission planning, and autonomous flight software continue to advance.

Soon precision height sensors, on-board wind sensors, and glide slope control capability will also contribute greater accuracy in the delivery of supply and personnel from high altitudes. The vision of 24-hr, fort-to-fighter resupply of troops in need is becoming a reality. **A**